Pop-up technology: what the data show us

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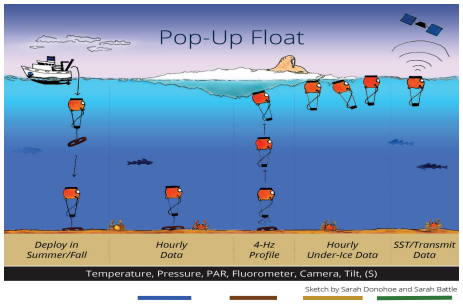
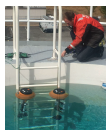


The pop-up float (PUF) was developed at PMEL and EcoFOCI as a low-cost solution to measure ocean temperature, with the specific intention of expanding in-situ measurements to monitor under-ice conditions in spring at the end of the ice season. Typically, pop-ups are deployed in summer, recording data on the seafloor until the following year when they surface at a predetermined time. These bottom temperature data have been used to delineate the evolution and extent of the cold pool in the eastern Bering Sea, especially in 2021-2023. In addition, upon surfacing they provide direct measurements under-ice, if ice is present, or sea surface temperature (SST). In 2018 and 2020, pop-up floats were deployed in the Chukchi Sea, adding a camera, PAR sensor, and fluorometer to the two thermistors. These data show the under-ice bloom, the magnitude of light (PAR), and the thinning of the sea ice. The photographs show the changing characteristics of chlorophyll under ice. The trajectory of pop-ups can be traced via satellite by following the ice floe that the pop-up came up under. Pop-ups are easily deployed and provide a relatively inexpensive source of bottom temperature, SST, and under-ice information.

Testing and Deployments

Pop-up deployed by the Coast Guard from USCGC Fir.



D.Langis testing PopUp units in a dive tank at PMEL during development;

Looking down at a PopUp deployment on a ship of opportunity, the catcher/processor Starbound

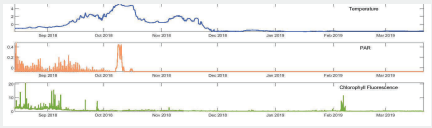
R.McCabe deploying a PopUp at sea.

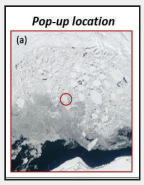
Crew and Pop-up prior to deployment on c/p Starbound.

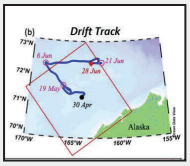
Four phases of data collection:

Bottom data | Profile data | Under-ice data | Surface data

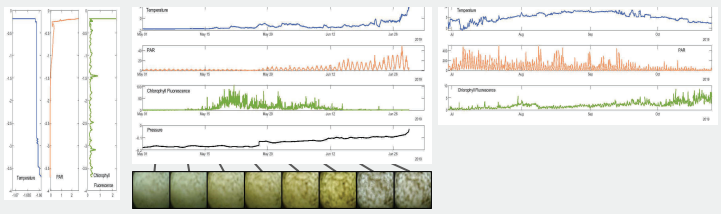
Sensors:
- Thermistor 1 (top, fast response time)
- Thermistor 2 (bottom, slower response)
- PAR
- Fluorometer
- Pressure
- Camera (side mount, angled slightly upward)





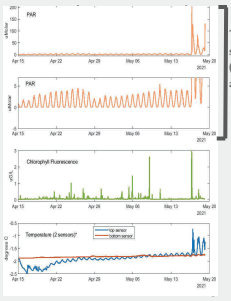


The red circle in the satellite image (above left) indicates the ice floe in the Chukchi Sea that a pop-up came up underneath. The floe transit was tracked using satellite images for approximately two months, and the resultant trajectory is shown above right. (ref. Stabeno et al., 2020)



Shown above are the four stages of data from one pop-up float. The deployment site was near C2 in the Chukchi Sea. It was deployed in late August 2018; it surfaced on 30 April and remained under the ice until 28 June. The last panel shows surface measurements until it failed at the end of October.

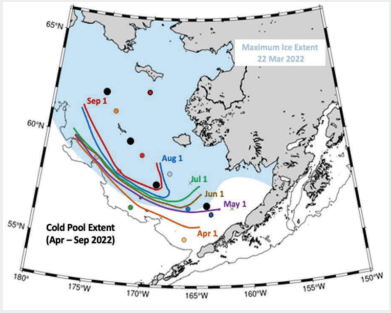
An interesting under ice event from 2021 at C2



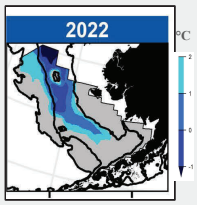
Two scales of PAR data show a late-record spike (top) mentioned below, and a diurnal cycle (bottom).

We hypothesize that after surfacing, this float was initially (April 15-29) embedded in rather than under the ice. This is reflected in the temperature signal (~ -2.2 °C) from Thermistor 1 (bottom left, blue line). The water slowly warms to ~-1.8 °C, which was the temperature at the bottom of the buoy (Thermistor 2). The more extreme values at the end of the record (17-20 May) reflect when the ice melted around the sensors.

Bottom temperature: Cold Pool, Bering Sea

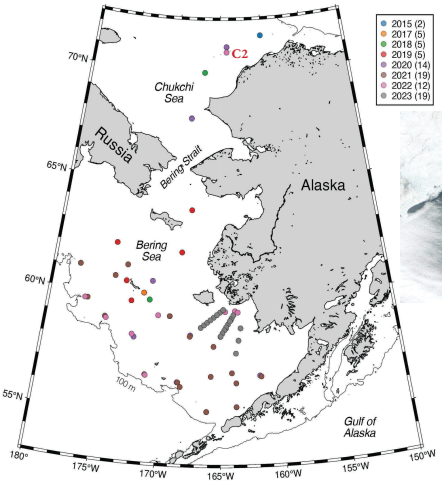


In 2022, 11 pop-up floats were situated on the eastern Bering Sea shelf measuring bottom temperatures (small circles, left). In addition, M2, M4, M5 and M8 were deployed. The PUFs were deployed as part of NPRB proposal (Evaluating historical and future climate- driven changes to Pacific cod spawning habitat in the Bering Sea, led by L. Rogers). Using these data, we mapped the changing cold pool from 1 April through 1 September. Maximum ice extent is indicated in blue shading. The "snap-shot" of the cold pool from the bottom trawl survey is indicated in the image to the right.

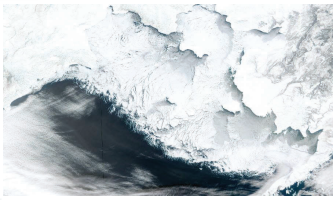


Temperature data collected by the NOAA AFSC/RACE Groundfish Assessment Program and the Eastern Bering Sea Bottom Trawl Survey group.

Pop-up locations, 2017-2023



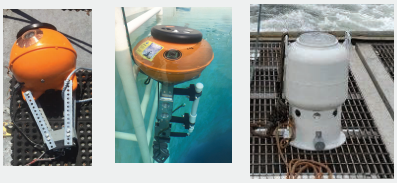
Ice on the eastern Bering Sea shelf



In designing the pop-up system, our focus was on robustness and affordability. Recognizing the risk of instrument loss, we ensure low-cost, recoverable data via satellite connection. Emphasizing environmental responsibility, we commit to almost 100% biodegradable packaging. The system is designed for the deployment by small fishing boats without the need for onboard expertise, featuring an overall weight under 35 kg and a depth rating of 200 m. The modular design supports the flexibility of adding and removing sensors, while two-way communication enables command transmission to the float.

Minimizing Plastics

Development of the pop-up has included reducing the use of plastic that may be left in the ocean. A steel case made out of empty propane cans is the current design.



References:

- Langis, D., P.J. Stabeno, C. Meinig, C.W. Mordy, S.W. Bell, and H.M. Tabisola (2018): Low-cost expendable buoys for under-ice data collection. In *Oceans 2018 MTS/IEEE Charleston*, Marine Technology

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